

Fuel Reformulation and Jet Fuel

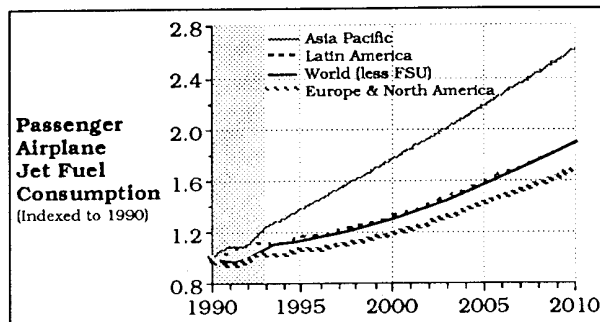
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Summation

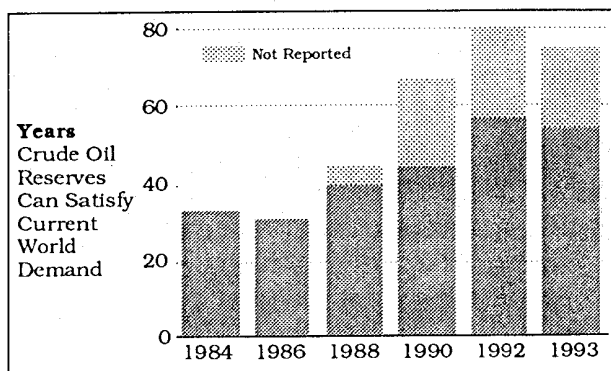
- Properties of jet fuel are being influenced by the reformulation of other fuels as well as changes in product demand.
- Decreases in fuel processing efficiencies increase cost and overall emissions of CO₂ and a variety of less-than-desirable process effluents.
- Increased hydrogenation of refined products and light crude oils containing low sulphur are leading to a cleaner more stable jet fuel.
- Effects of changes in the sources and composition of jet fuel on fuel properties are not completely understood.
- The reformulation of fuels and a shifting product demand are likely to continue well into the next century.

This paper examines changes that are beginning to influence the characteristics and cost of the fuel needed to support the growth in aviation.^[1] These changes are precipitated by responses to concerns for the environment and by shifts in product demand.

New discoveries of oil outside the Middle East make it apparent that the world reserves of petroleum are sufficient to last well into the next century. Occasionally, conditions such as a low price for oil discourage exploration, and there is a slowing in the discovery of new reserves. However, exploration stimulated by relatively small tightenings of the oil market, new technology, and access to potentially massive untapped oil fields in the former Soviet Union (FSU), will work to return oil reserves to a point where additions at least balance consumption.



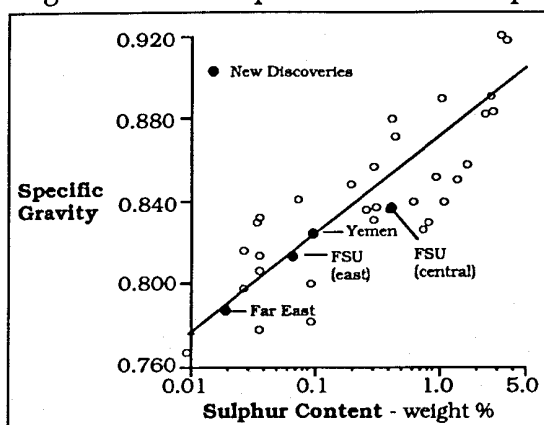
The demand for air travel will continue to grow, particularly in the Asia Pacific



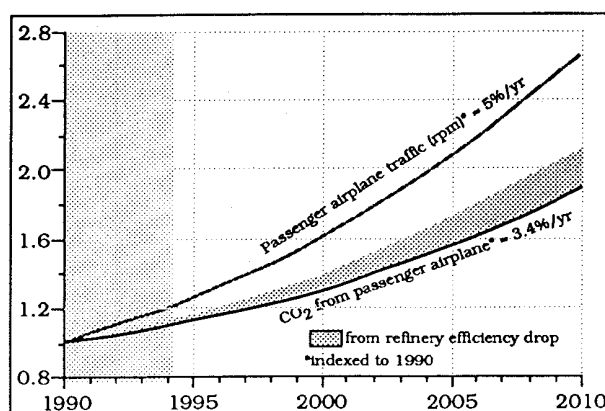
Reserves of petroleum \leq \$20 per barrel are sufficient to last well into the next century

A prevailing opinion outside, and to a lesser degree within, the petroleum industry is that crude oils will continue to get heavier and their sulphur content will steadily in-

crease. This is not supported by data. Although there is no precise relationship between the specific gravity of crude oils and the depth at which they are found, data indicate that deeper wells tend to contain the lighter crude oils. It can also be shown that the lighter oils tend to have low sulphur content. Therefore, as the search for oil goes deeper, a trend toward lighter, low-sulphur oils is more likely for the future than one toward heavier oils with high sulphur. This portends the possibility that more of the regulations proposed to control the cleanliness of fuels may be met by natural occurrence rather than expensive highly inefficient fuel processing. In the long term this could become important, because it is not clear which will be more necessary: reducing CO₂ to impede global warming or cleaning the air in urban areas. Regulation to clean the air that lead to more fuel processing increase the overall production of CO₂.

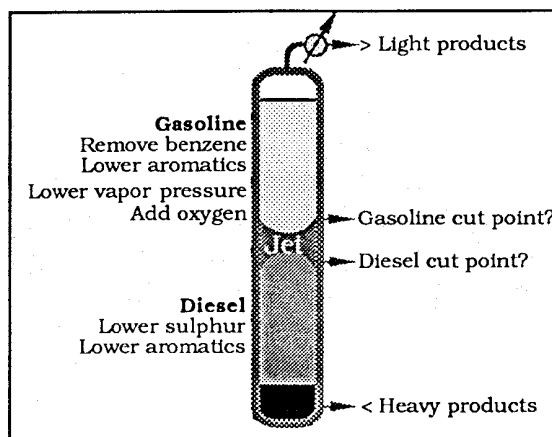


New oil discoveries are likely to be light with low sulphur



Processing efficiency losses will counter gains in user efficiency

On a global basis, losses in processing efficiency will counteract at least some of the efficiency gains made by fuel users, such as aviation. If controls on fuel composition and user emissions become more restrictive, there is a danger that the long-term net improvement to the environment may be slight.^[2] Many regulations are geared to solve local pollution problems, such as those that address ozone and carbon monoxide levels in cities. Technical studies must go beyond local problems to ensure that the long-term impact of a regulation is fully understood.



The reformulation of gasoline and diesel will change the properties and cost of jet fuel

Although few environmental regulations are aimed specifically at jet fuel, regulations governing other distillate fuels and gasoline are indirectly changing the composition of jet fuel and adding to its cost. Even before regulation forced the reformulation of fuels, changes in product mix away from heavy high-sulphur boiler fuels caused more

hydrotreating and blending of refinery streams.^[3] Changes in product demand have also made it economically necessary for refiners to maintain product flexibility to the point where it is impractical to isolate totally the various fuels. A realization that this trend will continue is causing some refiners to consider offering one distillate fuel that can satisfy specifications for heating oil, diesel, and jet fuel. Even if this does not happen, environmental regulations requiring the reformulation of one fuel will affect both the cost and properties of the others. Therefore, the aviation industry must pay attention to changes in all fuels, not just jet fuel.

Fuel Reformulation

Regulations forcing reductions in the sulphur content of diesel have been imposed in the United States, Europe, and parts of the Asia-Pacific region.^[4] Limits on the aromatic content of diesel have been established in Scandinavia and California. Hydrotreating is required to reduce sulphur; severe hydrotreating is required to reduce aromatics. Regulations covering the sulphur and aromatic content of diesel are expected to spread. In anticipation of this, some refiners are developing the capability to "zero out" the sulphur content of all distillate fuels, particularly in the growing markets of the Far East, where it makes sense to build new refineries.

During the early 1970s it was determined that lead in gasoline was a health problem, and a staged phase-out of lead was mandated in the United States. The phase-out of lead has now spread through most of the world. Until recently, the loss of gasoline octane caused by the lead reduction was offset by the addition of aromatics. Aromatics were manufactured for this purpose by reforming hydrocarbons in a catalytic process that removes hydrogen from saturated hydrocarbons. The byproduct hydrogen is used to desulphurize distillate fuels. Now, regulations in the United States restrict the aromatic content of gasoline to a level where the use of reformers as a source of hydrogen is being severely diminished.^[5] In 1991 reformer hydrogen accounted for 68% of the hydrogen demand in U.S. refineries.^[6] Reformer hydrogen is likely to account for less than 40% of the demand by the year 2000. A rapid rise in the demand for hydrogen and the need for its manufacture is also expected outside the United States, particularly in the Asia-Pacific region. Therefore, much of the hydrogen required to reduce the sulphur and aromatic levels of distillate fuels must now be: (1) manufactured from low-value products produced in the various refining processes; (2) manufactured from natural gas; or (3) purchased on the open market.^[7] The manufacture of hydrogen requires the expenditure of energy; hence, the more hydrogen required for this processing, the lower the thermal efficiency of the refinery. Depending upon the feedstock, pressure, and purity requirements, the efficiency of manufacturing hydrogen ranges from 60% to 78%.

$$\text{Thermal Efficiency} = \frac{\text{Energy (finished product)}}{\text{Energy (Raw Material)} + \text{Energy (Process)}}$$

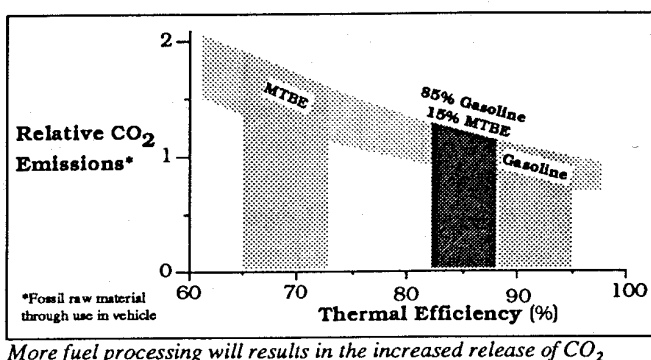
All processing reduces efficiency

Starting in November 1992, gasoline sold in 41 U.S. cities that did not meet the government mandated carbon monoxide (CO) limit had to be blended with an oxygenate until

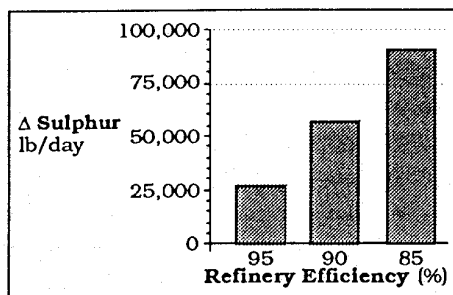
its oxygen content reached 2.7 wt.%. Most of these cities required that gasoline be oxygenated for only four months during the winter; some, like New York, required it for a longer period of time.^[8] In addition, areas that exceed ozone (O₃) limits will require re-formulated gasoline containing at least 2.0 wt.% oxygen by January 1, 1995.^[9]

Oxygen is added to gasoline in the form of ethers or alcohols. The most-used ether is methyl tertiary butyl ether (MTBE). It must be added to a concentration of 15 vol.% in gasoline to satisfy the 2.7 wt.% oxygen requirement. Ethyl alcohol (ETOH) can satisfy the requirement at a concentration of 10 vol.%. During the past winter, oxygenates were added to approximately 40% of the U.S. gasoline supply. The practical aspects of gasoline refining and distribution dictate the sale of considerably more oxygenated gasoline than that mandated by regulation.

The addition of oxygen to gasoline drops the thermal efficiency of fuel processing. For example: MTBE produced with a 65% to 73% thermal efficiency replaces gasoline produced with a thermal efficiency of 89% to 95%. This drop in efficiency, like that associated with the hydrogenation of fuels, results in the increased production of CO₂.^[10] Furthermore, and often forgotten, a lowering of fuel processing efficiency will:



- Increase the requirement for the disposal or removal of contaminants contained in refinery fuel. Currently much of this refinery fuel comes from natural gas, which has much lower levels of contaminants than crude oils. Changes in product demand and economics are increasing the use of low-value products derived from the crude oil feedstock as fuel. This appreciably increases the requirement for disposing of contaminants. For example: an 85% efficient 100,000-barrel-per-day refinery using a Mexican export crude oil containing 1.7 wt.% sulphur^[11] must sell as a byproduct or dispose of 90,000 lb of sulphur per day in addition to the 511,100 lb per day of sulphur in the crude oil that is converted to saleable products.

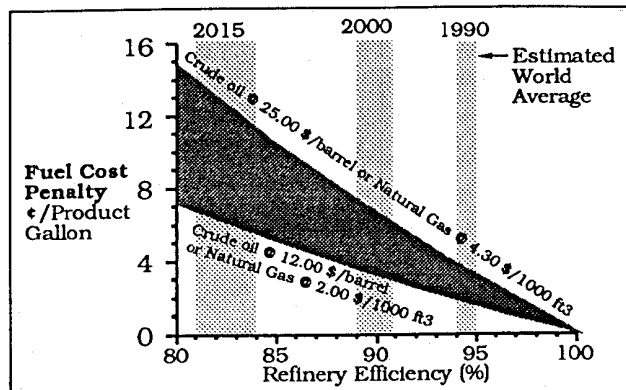


More fuel processing will result in the increased release of all process effluents as well as CO₂

- Produce more of any noxious byproduct associated with the chemical processes and generation of power.

- Increase emissions of all process effluents, such as NO_x, at the specific facilities threshold for removal or scrubbing each effluent.

Fuel manufacturing costs are increasing as a result of continuing decreases in refinery efficiency. This trend will continue, because changing product demand and environmental regulation will lead to more increases in the severity and complexity of crude oil processing. Whereas the effect on the price of products caused by drops in refinery efficiencies may be hardly noticeable in stable times, it could be quite severe when the price of energy goes through a period of precipitous increases, such as during the Persian Gulf war.^[12] This is because energy price increases apply to refinery fuel as well as to the product. Particularly costly are regulations that require the removal of a specific component, such as sulphur, and those that require manufactured additives, such as methyl tertiary butyl ether (MTBE).



Drops in processing efficiency will amplify effects of crude oil and natural gas price increases

Requirements for the reformulation of fuels are still being developed. Therefore, it is difficult to estimate how low fuel production efficiencies will go. However, the following worldwide efficiency-reducing actions are expected:

- Intensification of efforts to reduce the sulphur and aromatic contents of fuels.
- Increased attempts to reduce emissions by requiring specific fuel formulations.
- Continuing decline in demand for low-value products, such as residual fuel and heating oils.
- Refiners with sophisticated equipment opting to produce one distillate fuel that satisfies the specifications for jet, diesel, and light heating oil.
- The use of products manufactured by synthesis from natural gas, refinery gases, heavy fuel oil, and possibly coal to increase the value of refinery products.^[13,14]

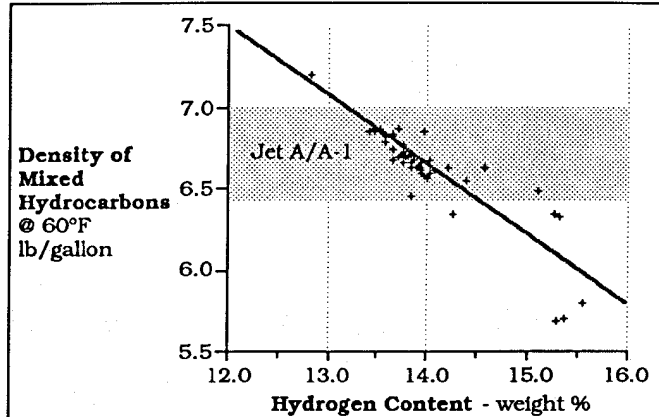
Changes in the Characteristics of Jet Fuel

It was anticipated that the increased use of hydrogenation to satisfy product demand and to reformulate fuels would eventually change the characteristics of jet fuel. Analyses of the effects of hydrogenation on fuel properties indicated that jet fuel density would be lowered, lubricity would drop, and there could be some unexpected changes.

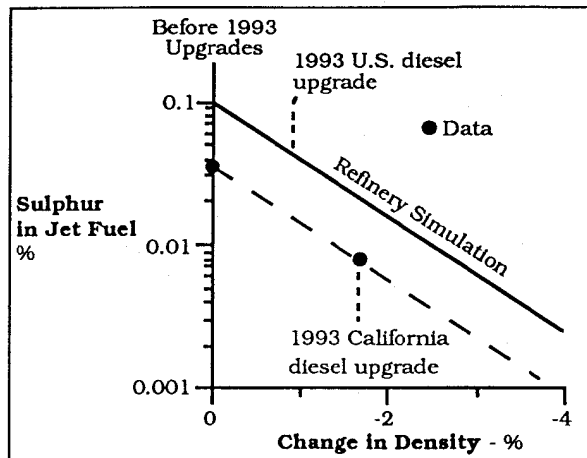
Density

It is impossible to assess how much the density of jet fuel would change as a result of increased hydrogenation, because it depends upon crude oil properties, refinery configuration, product mix, and the price of jet fuel relative to other fuels, such as diesel and gasoline. Nevertheless, a refinery simulation indicated that a decline in the density of jet fuel could be expected in the United States as a result of diesel reformulation regulations that became effective in October 1993. This decline would be particularly noticeable in California, where regulation forced severe hydrogenation of the distillate fuel pool because it reduced the aromatic content of diesel to as low as 10 vol.% and sulphur to 0.05 wt.%. The national regulation required a reduction only in sulphur. Results of the simulation have been qualitatively verified by comparing the density of jet fuel before and after refineries began to satisfy requirements of the regulation.

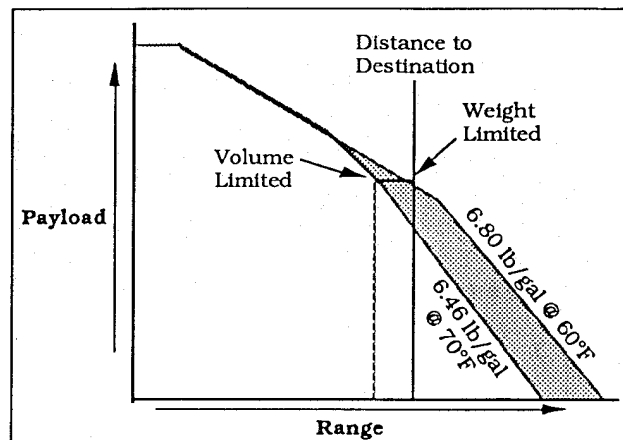
Historically, the density of fuel delivered to Los Angeles International airport (LAX) averaged 6.80 lb/gal (@ 60°F). This relatively high density resulted from the use of heavy California crude oil along with highly aromatic crude oils in local refineries. Hydrotreating required to satisfy new environmental regulations has reduced the tie between crude oil and the properties of products. Therefore, the current increase in the frequency of California jet fuel deliveries with densities below the historical 6.8 lb/gal was expected. Jet fuel with a density of 6.50 lb/gal (@ 60°F) has been delivered to LAX. If this fuel remains in the tank of an aircraft during the early part of the day, it can heat up to a point where the topped-off-at-the-



The density of jet fuel goes down as its hydrogen content increases



Fuel reformulation will cause the density of jet fuel to drop



A drop in fuel density can cause an aircraft to go from weight to volume limited

gate fuel temperature could be close to 70°F. This gives an effective fuel density of 6.46 lb/gal, which can cause aircraft scheduled for long flights, such as from LAX to Hong Kong, to go from weight to fuel volume limited.

Boeing, airline, and oil company data were used to determine the densities of jet fuel delivered to major regions of the world during 1990. The average of these densities, weighted by the quantity delivered, was found to be 6.71 lb/gal. Since that year, airline experience shows that the average density of jet fuel is dropping and the frequency of

deliveries with densities in the low end of the range is increasing. Analyses were conducted by region to estimate jet fuel densities likely to be found beyond the year 2000. These analyses included effects of environmental regulations, growth in product demand, and shifts in the type of product required. For example: natural gas will replace residual fuel oil as the primary power generation fuel in the Asia-Pacific region; fuel desulphurization will be required worldwide. The density average weighted by quantity for jet fuel resulting from these studies was 6.64 lb/gal.

Region	Av.	Densities (lb/gallon - at 60°F)			
		1990 High	Low	2000+ High	Low
U.S.A. (West of Rockies)	6.81	6.90	6.62	6.62	6.90
U.S.A. (East of Rockies)	6.75	6.87	6.65	6.65	6.80
Canada	6.75	6.90	6.70	6.80	6.90
Western Europe	6.65	6.70	6.64	6.65	6.70
Asia Pacific	6.63	6.68	6.48	6.62	6.70
Latin America	6.63	6.68	6.57	6.60	6.47
World Average (weighted by quantity)	6.71			6.64	

A positive result of increased hydrotreating is that the heat content of jet fuel, in terms of mass (ΔH_w), increases as its density decreases. Unfortunately, for every 1.0% decrease in density there is an 0.8% decrease in energy per unit volume with only a 0.2% increase in energy per unit mass. A relation between density (ρ) and heat content (ΔH_w) was developed from data obtained from a Boeing test program involving precision laboratory analyses of jet fuel samples collected at airports around the world. The relation [$\Delta H_w = 21,669 - 464.6\rho_{(60^\circ\text{F})}$] has proved to have a 3σ (3-standard-error-of-estimate) of $\pm 0.5\%$.^[15]

Region	1990		2000+	
	Density (lb/gal)	LHV (Btu/lb)	Density (lb/gal)	LHV (Btu/lb)
U.S.A. (West of Rockies)	6.81	18,506	6.62	18,594
U.S.A. (East of Rockies)	6.75	18,533	6.65	18,580
Canada	6.75	18,533	6.80	18,510
Western Europe	6.65	18,580	6.65	18,580
Asia Pacific	6.63	18,589	6.62	18,594
Latin America	6.63	18,589	6.60	18,603
Jet A-1 minimum	6.45	18,400		
Jet A-1 maximum	7.00			
Average densities at 60 °F				

It is too early to tell how low the density of jet fuel will go. The specification minimum density for kerosene-type jet fuel is 6.45 lb/gal (@ 60°F). It is doubtful that many loads of jet fuel will have the minimum density. It is also not clear whether fuel density will play an important part in flight planning or just be a minor annoyance. Airlines that fine-tune their fuel load based on history are the most likely to have problems with vol-

ume-limited flights. Fine-tuning is also likely to show that densities are not just changing, but are changing more frequently — sometimes hourly rather than daily.

Lubricity

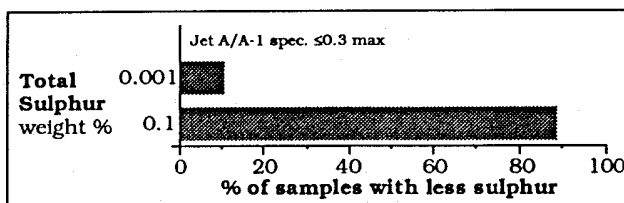
Experiences with equipment shows that highly hydrotreated fuels tend to have poor lubricating properties.^[16] Therefore, if no action is taken, the increased hydrogenation of fuels might eventually result in more maintenance and shorter lives for aircraft engine fuel pumps.

At best, jet fuel is considered a marginal lubricant. Although fuel lubricity has been researched and debated since the late 1960s, there is no clearly identified chemical species whose presence or absence allows the acceptance or rejection of a fuel because of lubricity.^[17]

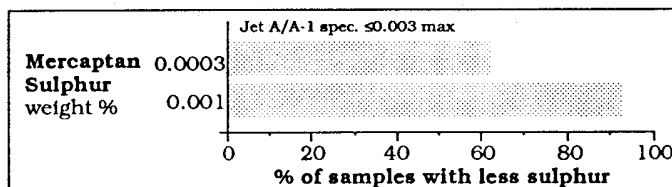
There is a growing consensus that lubricity has more to do with traces of polar material than the presence of any single compound.^{[18] [19]} Because the most notable of these are the sulphur-containing organic compounds, some believe that the sulphur level of jet fuel should have a minimum limit as well as a maximum. However, a minimum limit for sulphur is not a reasonable solution for obtaining acceptable fuel lubricity for the following reasons:

- The worldwide market for petroleum products is forcing a reduction in the sulphur content of jet fuel. Therefore, requiring a minimum sulphur level in jet fuel would make it a specialty product, hence put upward pressure on its price.
- Fuel samples collected by Boeing at airports around the world in 1989 revealed that approximately 10% of the jet fuel deliveries already had a total sulphur content below 0.001 wt.%. This is essentially zero in terms of a practical product composition control measurement limit.
- Any positive effect sulphur compounds have on lubricity would be offset by their potential for increasing corrosiveness, lowering thermal stability, degrading elastomers, and producing noxious odors.

Elastomer and odor problems are particularly linked to mercaptans. In the past mercaptans were reduced by chemical processing techniques.^[20] Now they are also



The total sulphur content in jet fuel will continue to decrease



Mercaptan sulphur will essentially disappear

being reduced or eliminated because of increased hydrotreating. Boeing data indicate that more than 50% of jet fuel deliveries have mercaptan levels below 0.0003 wt.% (i.e. the detection limit). None of the fuel samples known to have been highly hydrotreated had measurable mercaptans.

- Placing a minimum limit on sulphur, or any other contaminant, in jet fuel would be counter to the desirability of going to cleaner fuels for environmental and efficiency/maintenance reasons.

Reports of pump and fuel controller wear and failure problems attributed to fuel lubricity have dropped considerably since the early 1970s. If increased hydrogenation reverses this trend, approved fatty acid corrosion-inhibiting additives can be used to improve lubricity.^[21] However, additives are not popular with airlines because they have some undesirable effects on filtration and add to the cost of fuel.^[22] The preferred solution to lubricity problems is for manufacturers to design components so that they tolerate fuels that are poor lubricants. The apparent drop in lubricity-caused problems indicates that some progress has been made in this direction. Another factor is the increased commingling of fuels from different sources in pipelines and at airports. The positive effect of commingling on lubricity will diminish as more of the jet fuel supply is composed of highly hydrogenated refinery streams.

Thermal Stability

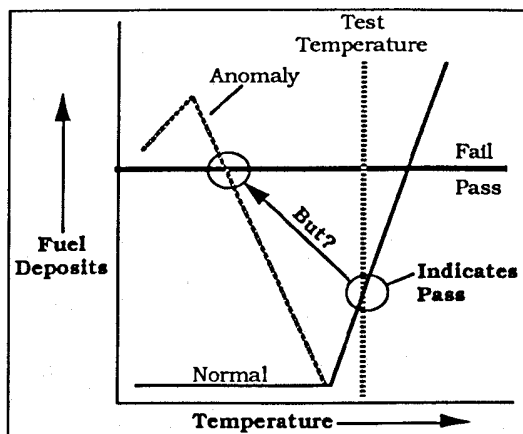
The term *thermal stability* is used to describe resistance of jet fuel to the formation of deposits on surfaces or filter plugging solid matter in fuel that is thermally stressed (heated). We do not know exactly what causes these formations.^[23] Most recent research points to oxidation reactions that are influenced by sulphur, fuel acidity, and trace metals.^[24]

The thermal stability of jet fuel should improve because of the increased hydrogenation of distillate fuels and the associated reduction in sulphur. However, there are many factors that make this improvement less certain. These are:

- The composition of jet fuels is changing as to both number and types of components and the processes used to refine fuels.
- Regulations that inadvertently introduce trace materials into the jet fuel stream, such as the U.S. Environmental Protection Agency's requirement for a dye in nonreformulated diesel fuel and the requirement of the U.S. Internal Revenue Service that nontaxed distillate fuels contain dye.^[25]
- Denaturing of fuel to prevent unauthorized use or supply disruption in nations with rapidly growing economies.

- Contamination of fuel in areas where the growth of aviation is putting pressure on the fuel supply and delivery infrastructure.

We must have a better understanding of thermally induced fuel deposition processes to establish their importance. As a minimum, new fuels should be characterized using more sophisticated tests than those developed to satisfy purchase specifications, such as the jet fuel thermal oxidation tester (JFTOT).^[26] Boeing data using a research version of this tester indicated that jet fuels with a hydrogen content above 14.0 wt.% are stable to temperatures at least 17°C higher than the 260°C JFTOT acceptance temperature. However, a fuel that satisfied this condition caused aircraft filter plugging problems. This plugging apparently resulted from the use of carbon disulphide as a denaturing agent. Boeing data have also shown that fuel deposits can form at temperatures lower than the test temperature and disappear at the test temperature. This phenomenon could be the result of changes in the solubility of thermal oxidation products or may simply result from changes in the solubility of dissolved contaminants.

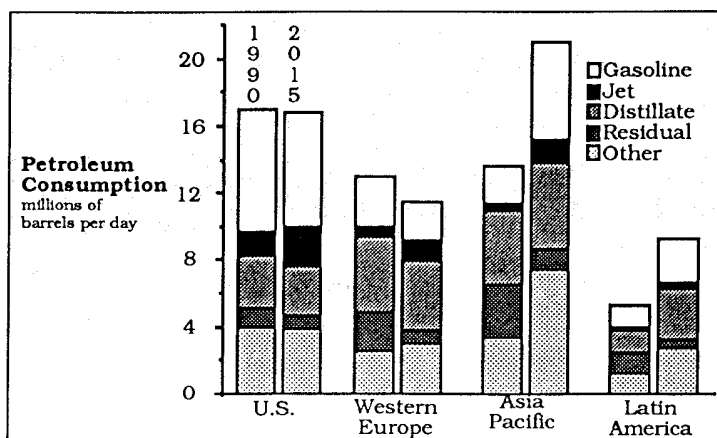


Current tests will not detect all fuel stability problems

Work is continuing that might lead to an improved explanation and characterization of solids in jet fuel.^[27,28] Until all the mechanisms of these processes are understood, unexplained filter plugging and the coating of hot surfaces are likely to recur..

Changes in the Composition of Jet Fuel

To date, changes in the chemical composition of jet fuel, such as a reduction in sulphur and increased hydrogen, have been subtle. In the future, the basic structure of jet fuel could change. New environmental regulations will continue to force more reformulation of fuels, beginning in the United States and spreading worldwide. Possibly more predominant, will be composition changes driven by the fuel processing adjustments needed to satisfy a falling market for low-value products, such as residual fuel oil. Reductions in the demand for these product are oc-



Changing fuel demand patterns will also effect the composition of jet fuel

curing in the face of an increasing demand for premium products, such as jet fuel, diesel, and chemical feedstocks. These changes started 20 years ago and are well advanced in the United States. They are occurring at a much faster pace in the Asia-Pacific region and will eventually take place in Latin America.

A long-term lowering of aromatic content in jet fuel and a reduction in the number and types of its components should be expected. Regulations and the shift in product demand will act to reduce aromatics. The reduction in the number and type of compounds will be caused by the increased use of blending stock synthesized

	Straight Run	Hydrotreater (blend)	Catalytic Cracker (blend)	Hydrocracker (blend)	Synthesized
Hydrogen (wt.%)	13.4	13.8	13.9	14.0	15.2
Sulphur (wt.%)	0.06	0.04	0.04	0.003	~0.00
Saturates (vol.%)	78.7	80.3	76.6	95.1	97.0
Aromatics (vol.%)	20.9	18.6	18.4	4.5	2.0
Olefins (vol.%)	0.4	1.2	5.0	0.4	1.0

Trend →

The composition of jet fuel will continue to change

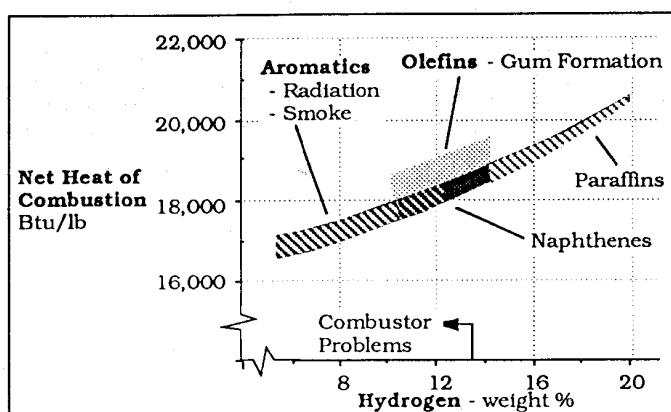
from natural gas, heavy oil, and coal. In the short term, the olefin content of jet fuel may increase. These olefins would come from catalytically cracked blending stock. This is likely to be a temporary situation occurring in areas of the world where the demand for transportation fuels temporarily outruns the modernization or construction of refineries, or in areas where refiners have little time to satisfy a new reformulation requirement.

Aromatics

During the oil crises of the 1970s, the aromatic content of jet fuel increased.^[29] This trend was expected to continue because increasing competition for a dwindling supply of distillate fuels would force the introduction of fuels derived from nonpetroleum feedstocks, such as coal. This belief led to various proposals for relaxing the jet fuel specification, particularly with respect to its aromatic content.^[30] However, higher energy prices stimulated the finding of new oil supplies; market considerations, not properties, dictated the availability of jet fuel.^[31]

In addition to market conditions, environmental regulations are now influencing the composition of jet fuel. The aromatic content of jet fuel is continuing to drop. Increasing numbers of jet fuel deliveries have aromatic contents below 10 vol.%. Jet fuel with less than 5 vol.% is likely to be common in the future.

Low-aromatic-content fuels burn clean, radiate less heat to engine



Higher hydrogen content fuel components tend to have desirable properties, olefins are an exception

components, and have a relatively high energy content per unit mass. They also tend to have a very high thermal stability. Thermal stability break points of 12 fuels with aromatic contents below 10 vol.% were determined. All had break points at least 20°C better than the 260°C normally required to satisfy jet fuel stability requirements,^[32] 58% had break points greater than 350°C. These 12 fuels included those synthesized from natural gas and coal as well as those refined from crude oil.

Now that more jet fuels with low or no aromatic content are being delivered, the possibility of such fuels causing leakage because of seal shrinkage is being revived. Boeing conducted seal and elastomer tests with a South African fuel derived from coal, which had less than 1.0 vol.% aromatics. Although not all-encompassing, these tests showed no adverse effects on sealants. Some O-ring shrinkage was observed after cycling between low and high aromatic fuels, but this shrinkage was not greater than that allowed in commercial practice or by applicable military specifications.^[33,34] Leakage problems caused by O-ring shrinkage usually involve installations where the O-ring has achieved a permanent set. Maintenance procedures that include the installation of new O-rings are the accepted solution to this type of leakage. When this, results of tests run by Boeing, and the positive aspects of low aromatic content fuels are considered, contentions that a minimum level must be established for aromatics in jet fuel are not supportable.

Olefins

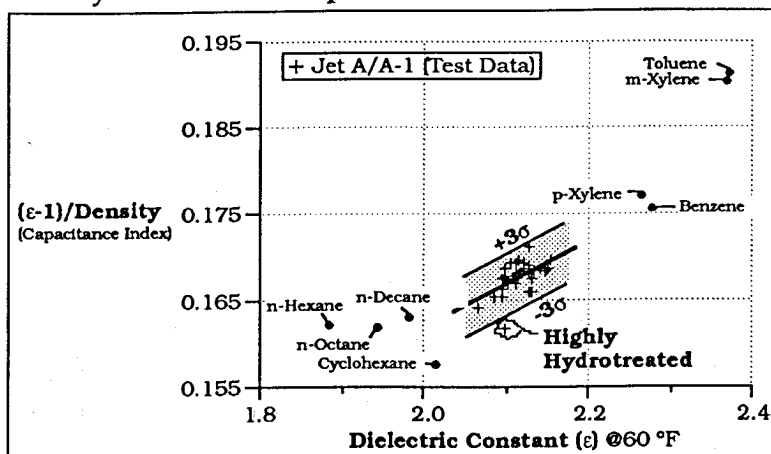
Although olefins can form gums by polymerization, they have not been a problem in jet fuel. The Jet A and Jet A-1 aviation fuel specifications do not limit olefins; most other specifications limit them to 5.0 vol.%. Olefins in jet fuel average about 1.0 vol.% worldwide. However, this level could increase in areas where the fuel is blended with streams from a fluid catalytic cracker, rather than from a hydrocracker. In the few cases where this has been observed, the olefin concentration was at the 5.0 vol.% limit. The need to use this blending stock for jet fuel may increase in the late 1990s and later disappear as refinery modification programs catch up with the demand for cleaner products.

It is a widely accepted belief that any olefin type or level that would cause gumming, shellacking, or plugging problems in aircraft would cause the fuel to fail the thermal stability test. However, we found no data that would confirm this belief. In addition, there has been little aircraft operating experience with jet fuels containing olefin-rich streams. Therefore, if the olefin content of jet fuels increases, particularly beyond 5.0 vol.%, stability testing involving both high (engine) and low (storage) temperatures will be required.

Other

Jet fuel is already becoming less complex in the number and type of its components. Increasing numbers of jet fuel deliveries have essentially no sulphur; future deliveries will have low or no aromatics. Later, more jet fuel will be at least partially made up of hydrocarbons synthesized from heavy oil, natural gas, and coal. The effects of these

changes should be mostly positive. Synthesis should produce fuels that burn clean and are highly stable thermally. However, these changes in composition will also affect any property that depends on the statistical convergence of a large number of different values to an average. An example of this is the capacitance index that relates volume to mass in the fuel quantity indicating systems used in many aircraft. Highly hydrotreated fuels and fuels with few



Changes in the makeup of jet fuels can radically change some properties

components may not follow the algorithm developed for this index. Other properties that may be affected by severe hydrotreating and changes in the number of components and species are: flash point, freezing point, electrical conductivity, solvency, and so forth. Data are not currently available that would allow a quantitative evaluation of these properties for the jet fuel types likely to be available in the future.

Outlook

The reformulation of fuels and a shifting product demand are likely to continue well into the next century. This will cause changes in the properties of jet fuel. The changes will not be radical, but will likely be quite noticeable and more variable at many airports than they have been in the past. This local variability will essentially eliminate the benefit of using specific route data from past flights for fine tuning fuel loads.

Changes to fuel properties will occur over enough time to allow us to identify and respond to adverse effects. However, surprises will be forthcoming if the current economically driven worldwide trend towards elimination of the capability to conduct fuel research continues.

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